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Effectiveness of Search Patterns for Recovery of Animal Carcasses in Relation to Pocket Gopher Infestation Control

G. W. Witmer,* M. J. Pipas & D. L. Campbell

USDA/APHIS Denver Wildlife Research Center, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164, USA

ABSTRACT

We tested four search patterns to identify one or more that consistently resulted in the location of a high percentage of above ground carcasses. Searchers found only 25·4% of placed carcasses. The random search pattern exhibited the lowest search efficiency (i.e. percent carcass recovery), 2·6%. This differed significantly from the other three search patterns (E/W transects; E/W transects followed by N/S transects; five randomly placed, 0·027-ha circular plots), which ranged in search efficiency from 24·5 to 36·2%. No significant difference in search efficiency over time was noted, and recovery rates were comparable in the morning and afternoon. Searchers did not differ in mean time spent searching or in carcass recovery efficiency. Carcass density did not influence search efficiency, but searchers found proportionally more carcasses on high carcass density plots. Starlings, the largest and least cryptically colored of the three carcass types, were recovered in the greatest proportion. Carcass degradation by various animals was confirmed to be an important contributor to rapid carcass deterioration. Selecting the best overall search pattern requires careful consideration of a number of factors. Because search efficiency was low regardless of search pattern, a substantial correction factor should be used to estimate the number of carcasses occurring on the surface after a baiting operation.

INTRODUCTION

When baiting pocket gophers (*Thomomys* spp.) it is often required as part of the registration process or as part of operational pocket gopher baiting

*To whom correspondence should be addressed.

to count or collect post-treatment above ground carcasses of target and non-target small mammals (Fite *et al.*, 1988). Information on above ground mortality would allow an assessment of hazards to non-target populations and specific chemical or biological analyses of dead animals.

Above ground carcasses are difficult to locate because of cryptic coloration, vegetation cover, carcass deterioration and removal by predators or scavengers (Colvin *et al.*, 1988). With burrowing animals, there is an additional problem: animals may die on the surface or underground. The proportion found on the surface can be low (Hegdal *et al.*, 1986) or high (Anthony *et al.*, 1984). Only a few or no carcasses may be found, even after extensive searching (Fagerstone *et al.*, 1980; Anonymous, 1965; Matschke *et al.*, 1984; Hegdal & Gatz. 1976; Hegdal *et al.*, 1986). However, in studies with placed carcasses, trained searchers, and prescribed protocols, the efficiency of finding can be quite high: 75–81% (Linz *et al.*, 1991; Tobin & Dolbeer, 1990). With radio-equipped animals, this problem can be satisfactorily resolved; however, costs and manpower requirements are often prohibitive.

Responsible agencies need a search protocol that will assure them of finding some carcasses on treated sites. The number of carcasses found (N) is related to several variables by the equation: $N = D\ R\ E\ A\ P$ (Fite *et al.*, 1988). Animal densities (D) can be estimated at the site using a variety of methods, or estimates from the literature can be used. The hectares searched (A) is under the control of the responsible agency; searches vary from less than 1 to 100% of the area treated. The proportion of the population killed (P) is usually high for target species using registered compounds; however, it can be low for non-target species because of bait specificity or bait placement or for target or non-target species with some experimental compounds. The proportion of carcasses remaining (R) drop off rapidly after treatment because of predator/scavenger activity and carcass deterioration (Balcomb, 1986; Sullivan, 1988; Bruggers *et al.*, 1989; Linz *et al.*, 1991; Tobin & Dolbeer, 1990). With acute toxins, carcass searches should begin the day after treatment. Search efficiency (E) can be high or low. The responsible agency needs to keep the search efficiency reasonably high, but this can only be done if the variables affecting search efficiency are considered in the design of a search protocol to estimate the number of carcasses not found. Once a search efficiency has been determined, a correction factor can be developed and used to estimate the number of carcasses not found. Fite *et al.* (1988) recommend that carcass searches only be conducted if there is a reasonable potential to detect mortality. This study was conducted to test four search patterns for identification of one or more that consistently resulted in the location of a high percentage of above ground carcasses.

METHODS

Study site

The study was conducted on a 70-ha reforestation area (T37S, R4E WM) of the Rogue River National Forest, Jackson County, OR. The unit was harvested as a shelterwood in 1978 with complete overstory removal in 1985. The first planting occurred in 1980, with subsequent replantings in 1986 and 1989 necessitated by repeated frost events. Site elevation is 4102 m. Vegetation is classified as the white fir (*Abies concolor*)/western serviceberry (*Amelanchier alnifolia*)/threeleaf anemone (*Anemone deltoidea*) plant association. Soils are gravelly to very cobbly loams. The substratum (bedrock) is composed of soft to moderately hard andesites, basalts and breccias. Depth to bedrock is about 2 m. Average annual precipitation is about 82 cm, falling mostly in the form of snow during the winter months. Average precipitation for the month of August is <2·5 cm, all from isolated thunderstorms. The days on which the carcass searches were conducted were clear, hot, and dry.

Experimental design

The study was structured as a randomized block design. Analysis of variance (ANOVA) (Ott, 1993) was used to test for significant differences between search patterns for search efficiency, overall time spent searching, search efficiency over time, search efficiency between searchers over time, overall time spent searching and vegetation effects on search efficiency. The unbalanced design resulting from a protocol deviation in the number of searchers required specialized statistical treatment in some cases. Duncan's multiple range test was used to define differences revealed by ANOVA. The *t*-test (Ott, 1993) was used to test for differences in search efficiencies between a.m. and p.m. searches and between less experienced and more experienced searchers and between carcass densities. A χ^2-test (Ott, 1993) was chosen to evaluate carcass recovery efficiency by carcass type (gopher, bird, small mammal). All significance tests were conducted at the $a = 0{\cdot}05$ significance level.

Plot searches

Field work was conducted 17–19 August, 1993. Sixteen replicate 0·4-ha, square plots were demarcated. Each of four individuals was to search each of four different plots using one of the search patterns. All searchers were to employ all four search patterns (total of 16 different plots searched per individual). Logistical problems necessitated a deviation from this plan and, instead of four searchers, six were employed. Two tested all four search patterns, the other four two patterns each. Each search pattern was tested by four searchers. All searchers were instructed in search protocol before starting searches and provided with time pieces to record search times. To eliminate a potential bias, information was withheld on carcass numbers placed in plots. The four search patterns employed in this study included: (1) E/W searches using parallel transects of a width subjectively determined by the searcher (single coverage); (2) E/W followed by N/S transect searches, as outlined above (double plot coverage); (3) random searches, the pattern left to the discretion of the individual (potentially multiple or no coverage of portions of each plot); (4) subplot searches using five 0·027-ha, non-overlapping circular plots randomly located by the searcher in each 0·4-ha square plot. No time constraints were attached to the searches. Searchers were to search each plot until they believed adequate coverage was attained. Upon locating a carcass, the searcher recorded the carcass type, mapped its location, and placed a wire flag at the location. The searcher did not handle or move the carcass.

After completion of a search, a verifier confirmed identifications made by the searcher and ensured that all carcasses were present and remained *in situ* or, if moved, were still potentially visible to the searcher. Telemetry equipment was used to relocate moved carcasses. Although some carcasses had been moved short distances from their original locations, they remained potentially visible to the searchers in all but three cases. An adjustment was made in evaluating search effectiveness in these three cases.

Carcass placement

Carcasses of five different species were used in the trials: northern pocket gopher (*Thomomys talpoides*), starling (*Sturnus vulgaris*) and other small mammals: vole (*Microtus* sp.), deer mouse (*Peromyscus maniculatus*), and chipmunk (*Eutamias* sp.). Sources of specimens included Forest Service contract trappers (gophers, chipmunk), snap trapping on Washington State University (WSU) grounds (voles, deer mice) and an unrelated research project at WSU (starlings). Each individual was fitted with a radiotransmitter rubber banded to the body and a uniquely numbered leg band and kept in an ice chest until use the next day. Each morning, just prior to arrival of the searchers, verifiers placed the carcasses. These were located in the plots at randomly selected coordinates relative to a fixed position (a flag marking the center of the plot) to facilitate relocations for verification work. The extremely hot weather accelerated carcass degradation so that these had to frequently be replaced with fresh ones. Carcass density, for convenience of data analysis, was fixed at two or four individuals per 0·4-ha plot. Species composition varied by plot, but every group of four plots (the blocking factor for each search pattern) remained at a constant ratio of 2:1:1 gopher:bird:small mammal (small mammal = vole, mouse, or chipmunk).

Vegetation characterization

Ocular estimates of tree, shrub, forb, grass, bare ground and woody debris cover and average grass/forb height were made for the 16 plots, as subgrouped by the four nearest 0·4-ha plots, to evaluate the influence of the vegetation (height and composition) on search efficiency. For each block of four 0·4-ha plots, spatially arranged in the pattern of a square, four 2 × 2 m microplots were centrally placed along with a 10 × 10 m plot for tree and shrub cover. Estimates of cover were made to the nearest 5%. Ground vegetation height was measured to the nearest 5 cm.

RESULTS

Overall search efficiency (i.e. percent carcass recovery) was low. Searchers found approximately one-fourth of all placed carcasses ($\bar{x} = 25{\cdot}4\%$, SE = 3·2, range = 0–100%). The random search pattern exhibited the lowest search efficiency (adjusted $\bar{x} = 2{\cdot}6\%$). This differed significantly from the other three search patterns (circular plots: adjusted $\bar{x} = 36{\cdot}2\%$; E/W transects: adjusted $\bar{x} = 31{\cdot}5\%$; E/W then N/S transects: adjusted $\bar{x} = 24{\cdot}5\%$), which did not significantly differ from each other, as shown in Table 1. Of the six searchers employed in the study, only two conducted searches with all four patterns. These two had the best search efficiency with the E/W ($\bar{x} = 40{\cdot}6\%$) and circular plot ($\bar{x} = 40{\cdot}6\%$) methods. For these two searchers, search efficiency did not differ significantly between the four search patterns ($F = 1{\cdot}38$, d.f. = 3, $p = 0{\cdot}27$). The search efficiency of two less experienced searchers was the same as two more experienced searchers, who used the same search patterns (Fig. 1). However, the two less experienced carcass searchers were trappers under contract to the government and hence were probably fairly observant of animals and animal signs in natural settings.

Time (sequential order of searches) did not influence search efficiency. No significant difference within search patterns in percent carcass recovery over time was noted (E/W transects: $F = 0{\cdot}65$, d.f. = 3, $p = 0{\cdot}60$; E/W then N/S transects: $F = 0{\cdot}19$, d.f. = 3, $p = 0{\cdot}90$; circular plots: $F = 1{\cdot}28$,

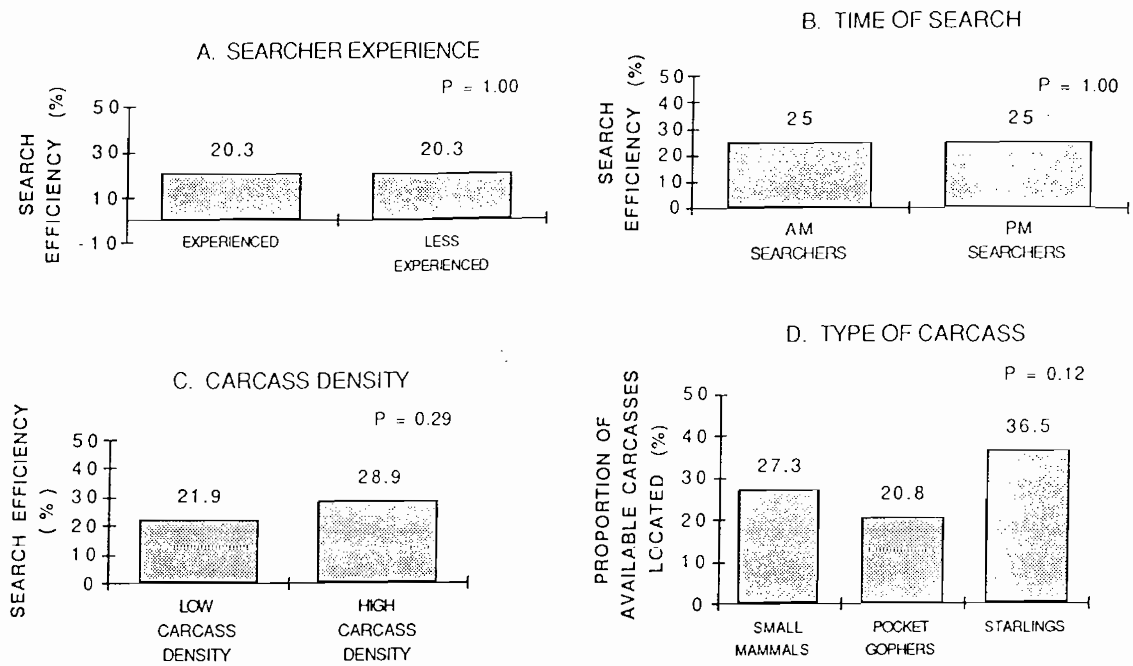

Fig. 1. Comparison of the ability to locate carcasses as related to searcher experience (A), time of search (B), carcass density (C), and type of search (D).

d.f. = 3, $p = 0{\cdot}33$; random searches: $F = 0{\cdot}43$, d.f. = 3, $p = 0{\cdot}74$). There was no significant difference between search efficiencies conducted in the morning vs the afternoon (Fig. 1).

Average time spent searching plots varied by search pattern, as shown in Table 1. The E/W then N/S transect pattern took significantly more time than either the random or E/W transect patterns which did not differ significantly from each other or the circular plot method. Searchers did not differ significantly ($F = 2{\cdot}09$, d.f. = 5, $p = 0{\cdot}08$) in mean time spent

TABLE 1

Adjusted Means and Standard Errors for Search Efficiency and Search Time for Four Carcass Search Patterns. There were no Significant Differences ($p > 0{\cdot}05$) between Means in a Column with the Same Letter Code

Search pattern	*Search efficiency (%)*	*Average time spent searching (min)*
Random	2·6 (6·7)^a	28·7 (4·0)^b
E/W transects	31·5 (6·7)^b	29·9 (4·0)^b
E/W then N/S transects	24·5 (6·7)^b	46·1 (4·0)^a
5 circular (0·027-ha) plots	36·2 (6·7)^b	41·1 (4·0)^b

searching (averaged across all search patterns) or in search efficiency ($F = 1{\cdot}37$, d.f. $= 5$, $p = 0{\cdot}25$).

Carcass density did not influence search efficiency. Although searchers had a better search efficiency on high carcass density (4 per 0·4 ha) plots than on low density (2 per 0·4 ha) plots, the difference was not significant (Fig. 1).

Of the three types of carcasses used (gopher, starling, small mammal), starlings were recovered in the greatest proportion (Fig. 1). Small mammals ranked second, followed by gophers. The differences in proportion of carcasses found was nonsignificant.

Perhaps because all 16 plots were on the same clearcut unit, vegetation cover varied to a relatively small extent between the four clusters of 0·4-ha plots. Tree and shrub canopy cover varied from 5–20 and <5–20%, respectively. Forb and grass cover varied from 15–35 and 10–40%, respectively. Bare ground and woody debris cover varied from 20–40 and 10–30%, respectively. The average height of forbs and grasses combined varied from 20 to 50 cm. There was no significant difference ($F = 2{\cdot}40$, d.f. $= 3$, $p = 0{\cdot}08$) between search efficiencies when they were divided into four groups based on the four clusters of 0·4-ha plots.

DISCUSSION

This study addressed a number of factors to be considered in conducting carcass searches related to search efficiency. Among these are search pattern, search time, carcass density, habitat features (vegetation height/structure) and variation among searchers.

Search pattern had a definite influence on search efficiency. The random search pattern method was by far the least efficient, implying that a systematic (E/W, E/W then N/S methods) or subplot structure (circular plot method) would be more efficient. The circular plot method gave the highest search efficiency, despite not being a complete area search, and consequently may be considered the best method tested.

Other factors, such as search time, enter into selection of a preferred search pattern. Although characterized by the highest search efficiency, the circular plot method ranked third in average time spent establishing plots and searching. No increasing trend in time efficiency of searches for any given pattern was noted by individual searchers; however, it would be expected that search time efficiency for any particular pattern would most likely increase with experience.

Individual searcher variation must also be considered when evaluating carcass search methodologies. Although in this study searchers did not differ in search times or search efficiency between plots, inherent differences in individuals can be expected. These are 'intangibles' that cannot be removed by instruction alone. However, a learning component must also be considered. Linz *et al.* (1991) documented that searcher proficiency in finding female red-winged blackbird (*Agelaius phoeniceus*) carcasses increased with successive trials. In this study, all searchers were instructed in protocol beforehand and appeared to be interested and motivated from the start. This is perhaps why we found no significant differences between searchers and search efficiency.

No detectable differences in search efficiency were noted with varying carcass density. Although only two density levels were tested (two or four carcasses per plot), this structure was adequate to reasonably evaluate high and low density situations which may be encountered under actual field conditions. Although higher search efficiencies occurred at higher carcass densities, the differences were not statistically significant. Potential confounding factors of carcass size and degree of cryptic coloration were eliminated by the blocking factor (i.e. same ratio of carcass types for each group of four plots any given searcher examined using one specific search pattern). These are important characteristics to consider in carcass searches, however.

Features of the vegetation itself have great potential to influence search efficiency. We did not detect differences in search efficiencies in the four areas of this study, perhaps because the vegetation was relatively similar across the clearcut unit. With greater variation in vegetation, we would expect reduced search efficiency where vegetation obscures the visibility of carcasses.

Although carcass disappearance rates were not specifically addressed in this study, they can be a significant factor influencing search efficiency. The importance of scavenging as a source of carcass disappearance has been well documented (Sullivan, 1988; Bruggers *et al.*, 1989; Tobin & Dolbeer, 1990; Linz *et al.*, 1991). In this study, despite the frequent verification checks on carcasses and constant presence of humans in the study area, some carcasses were partially eaten or moved considerable distances, presumably by mammalian and/or avian scavengers. One gopher carcass had been moved to the top of a root wad of a wind-fallen tree >1 m above the ground surface.

Insects can also be a significant contributor to carcass deterioration. Sullivan (1988) documented rapid degradation of Columbian ground squirrel (*Spermophilus columbianus*) carcasses by insects, primarily flies. Tobin and Dolbeer (1990) also demonstrated the role of insects in carcass deterioration. In the current study, although the short time frame of the study (3 days) and prompt replacement of deteriorating carcasses with fresh ones undermined the role of insects in carcass disappearance, and by extension, search efficiency, insects proved important from another standpoint. Flies and hornets quickly located carcasses and were often so dense on these that, in some cases, they served as key informants to searchers of carcass location. More than one searcher mentioned this, and at least one indicated that he took advantage of this as an aid to locating carcasses. Odor from these small carcasses apparently did not serve as a cue. Weather (very high temperatures) was most likely a contributing factor to insect densities on carcasses. Thus, weather conditions may play an indirect role in search efficiency.

The effects of carcass size and degree of cryptic coloration were not specifically examined in this study, although it was demonstrated that of the three carcass types (gopher, starling, small mammal), starlings alone were recovered proportionally most frequently. Although no concrete conclusions can be drawn from this, coloration of starlings was the least cryptic and body size the largest of all species tested. Linz *et al.* (1991) noted that a larger number of male than female red-winged blackbirds were recovered by carcass searchers. They attributed this to the larger body size and more brightly colored epaulets characteristic of the male sex.

It is apparent from this study that a number of factors can influence the rate of carcass recovery. Overall, carcass recovery rates were low despite the various approaches and factors assessed in this study. This suggests that a substantial correction factor should be used to estimate actual carcass occurrence based on the results of carcass searches. Results of this study indicate that three to four carcasses may be present on the surface for every one found by searchers.

CONCLUSIONS AND RECOMMENDATIONS

Maximum search efficiency (i.e. percent carcass recovery) was attained using a systematic (E/W, E/W then N/S transect methods) scheme or a subsampling (circular plot method) structure. These were significantly more efficient than using a random search pattern. Time efficiency must also be considered when selecting a search protocol. The random method was the most time efficient (based on adjusted means), followed closely by the E/W transect method, then the circular plot method and E/W then N/S transect method. Searcher efficiency did not vary over the course of the day nor did it vary among searches, given that all were reasonably experienced in, or proficient at, looking for animal carcasses in natural settings. Searchers exhibited a somewhat greater search efficiency at high carcass densities than at low carcass densities. This, however, was to be expected. The vegetation profile (structure/composition), which varied only slightly across the study site, did not influence search efficiency. Carcass size and degree of cryptic coloration can influence searcher efficiency. Of the three carcass types (gopher, small mammal, starling), the largest and least cryptically colored, starlings, were recovered most frequently. Carcass disappearance rates, though not specifically addressed in this study, were rapid. Additionally, insects in large numbers on the carcasses aided some searchers in locating carcasses. Although not quantified, this may influence search efficiency. A substantial correction factor should be used to estimate actual carcass densities based on the results of carcass searches. For every carcass found by searchers, 3–4 may be present on the surface.

REFERENCES

Anonymous (1965). How easy is it to find the corpses? *Oryx*, **8,** 154–155.

Anthony, R.M., Lindsey, G.D. & Evans, J. (1984). Hazards to golden-mantled ground squirrels and associated secondary hazards potential from strychnine for forest pocket gophers. In: *Proc. Vertebr. Pest Conf.*, Vol. 11, pp. 25–31.

Balcomb, R. (1986). Songbird carcasses disappear rapidly from agricultural fields. *Auk*, **103,** 817–820.

Bruggers, R.L., Jaeger, M.M., Keith, J.O., Hegdal, P.L., Bourassa, J.B., Latigo, A.A. & Gillis, J.N. (1989). Impact of fenthion on nontarget birds during quelea control in Kenya. *Wildl. Soc. Bull.*, **17,** 149–160.

Colvin, B.A., Hegdal, P.L. & Jackson, W.B. (1988). Review of non-target hazards associated with rodenticide use in the U.S.A. *Bulletin OEPP*, **18,** 301–308.

Fagerstone, K.A., Barnes, V.G., Anthony, R.M. & Evans, J. (1980). Hazards to small mammals associated with underground strychnine baiting for pocket gophers. In: *Proc. Vertebr. Pest Conf.*, Vol. 9, pp. 105–109.

Fite, E.C., Turner, L.W., Cook, N.J. & Stunkard, C. (1988). Guidance document for conducting terrestrial field studies. EPA 540/09-88-109. US Environmental Protection Agency, Washington, DC. 67 pp.

Hegdal, P.L. & Gatz, T.A. (1976). Hazards to wildlife associated with underground strychnine baiting for pocket gophers. In: *Proc. Vertebr. Pest Conf.*, Vol. 7, pp. 258–266.

Hegdal, P.L., Fagerstone, K.A., Gatz, T.A., Glahn, J.F. & Matschke, G.H. (1986). Hazards to wildlife associated with 1080 baiting for California ground squirrels. *Wildl. Soc. Bull.*, **14,** 11–21.

Linz, G.M., Davis, J.E., Engeman, R.M., Otis, D.L. & Avery, M.L. (1991). Estimating survival of bird carcasses in cattail marshes. *Wildl. Soc. Bull.*, **19,** 195–199.

Matschke, G.H., Stickley, A.R., Christman, S.P., Lindsey, G.D. & Cochrane, R. (1984). Hazards to birds and mammals following nifluridide baiting for controlling fire ants. In: *Proc. Southeastern Assoc. of Fish Wildlife Agencies*, Vol. 38, pp. 239–255.

Ott, R.L. (1993). *An Introduction to Statistical Methods and Data Analysis*. 4th edn. Wadsworth, Belmont, CA, 1038 pp.

Sullivan, D. (1988). Determination of the environmental fate of ground squirrel carcasses. In: *Proc. Vertebr. Pest Conf.*, Vol. 13, pp. 169–173.

Tobin, M.E. & Dolbeer, R.A. (1990). Disappearance and recoverability of songbird carcasses in fruit orchards. *J. Field Ornithol.*, **61**, 237–242.